CBSE Class 12 Physics Board Paper 2026 (55/4/1) with Solutions

PREVIOUS YEAR PAPER · CLASS XII · PHYSICS (042) · BOARD EXAM 2026 · Q.P. CODE 55/4/1

TIME ALLOWED	MAXIMUM MARKS	QUESTIONS	NAME / ROLL NO.
3 hours	70	33 (A 16 · B 5 · C 7 · D 2 · E 3)	

GENERAL INSTRUCTIONS

Read the following instructions very carefully and strictly follow them:

1. This question paper contains 33 questions. All questions are compulsory.
2. This question paper is divided into five sections – Sections A, B, C, D and E.
3. In Section A – Questions no. 1 to 16 are Multiple Choice type questions. Each question carries 1 mark.
4. In Section B – Questions no. 17 to 21 are Very Short Answer type questions. Each question carries 2 marks.
5. In Section C – Questions no. 22 to 28 are Short Answer type questions. Each question carries 3 marks.
6. In Section D – Questions no. 29 and 30 are case study-based questions. Each question carries 4 marks.
7. In Section E – Questions no. 31 to 33 are Long Answer type questions. Each question carries 5 marks.
8. There is no overall choice given in the question paper. However, an internal choice has been provided in few questions in all the Sections except Section A.
9. Use of calculators is not allowed.
10. You may use: $c = 3 \times 10^{8}$ m/s; $h = 6.63 \times 10^{-34}$ J s; $e = 1.6 \times 10^{-19}$ C; $\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}; $\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 N^{-1} m^{-2}; $1/(4\pi\varepsilon_0) = 9 \times 10^{9}$ N m^2 C^{-2}; mass of electron 9.1×10^{-31} kg; mass of neutron 1.675×10^{-27} kg; mass of proton 1.673×10^{-27} kg; Avogadro's number 6.023×10^{23} per gram mole; Boltzmann constant 1.38×10^{-23} J K^{-1}.
11. This is the official 2026 board paper (Q.P. Code 55/4/1). The step marks shown in the solutions are our marking scheme in the CBSE style; CBSE's own marking scheme may award steps differently.
12. The answer key and the marking scheme are at the end of this booklet. Attempt the paper in 3 hours before you look at them.

Questions: CBSE board examination 2026, Q.P. Code 55/4/1, as published by CBSE at cbse.gov.in; figures redrawn. Answers, step marks and worked solutions © Master Testing Agency. Free for personal practice; not for resale. Master Testing Agency is an independent test-prep publisher, not affiliated with, endorsed by or connected to the Central Board of Secondary Education (CBSE) or any other exam-conducting body.

Chapters: Full syllabus · **Topics:** Electric Charges and Fields · Electrostatic Potential and Capacitance · Current Electricity · Moving Charges and Magnetism · Magnetism and Matter · Electromagnetic Induction · Alternating Current · Electromagnetic Waves · Ray Optics · Wave Optics · Dual Nature of Radiation and Matter · Atoms · Nuclei · Semiconductor Electronics

SECTION A

Multiple choice questions of 1 mark each (Q13–16 assertion-reason).

1. Two wires of same length and same area of cross-section but made of different material of resistivities ρ_1 and ρ_2 are connected in series. The equivalent resistivity of the combination is : 1

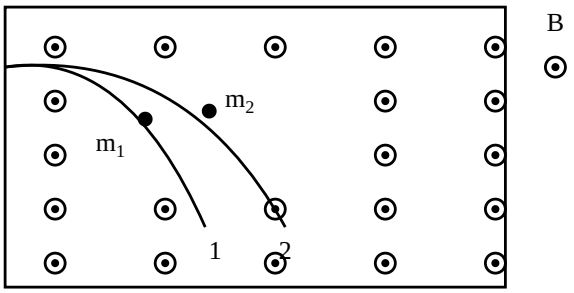
(A) $\frac{1}{2}(\rho_1 + \rho_2)$

(B) $\rho_1 + \rho_2$

(C) $\sqrt{\rho_1 \rho_2}$

(D) $2\,(\rho_1 + \rho_2)$

2. Two particles of masses m_1 and m_2 having charges q_1 and q_2 respectively are projected with the same velocity in a region of uniform magnetic field **B** pointing vertically upward. If they describe circular paths as shown in the figure, one may conclude that : 1



(A) $\frac{m_1}{m_2} > \frac{q_1}{q_2}$

(B) $\frac{m_1}{m_2} > \frac{q_2}{q_1}$

(C) $\frac{m_1}{m_2} < \frac{q_1}{q_2}$

(D) $\frac{m_1}{m_2} < \frac{q_2}{q_1}$

3. An electron moves around the nucleus in a circular orbit of radius r and makes n revolutions per second. The value of equivalent current in the orbit is : 1

(A) $\frac{e}{n}$

(B) ne

(C) $\frac{ne}{r}$

(D) $\frac{e}{nr}$

4. The dimensions of the rate of change of magnetic flux are : 1

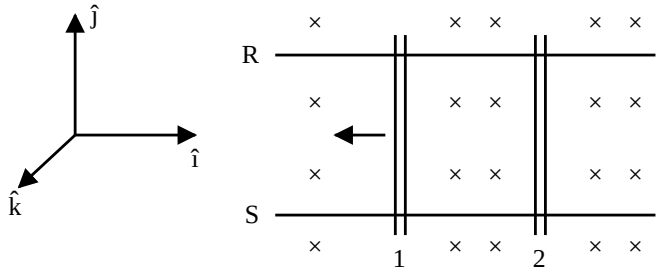
(A) $[M\,L\,T^{-3}\,A]$

(B) $[M\,L^2\,T^{-3}\,A^{-1}]$

(C) $[M\,L^2\,T^{-2}\,A^{-1}]$

(D) $[M\,L^2\,T^{-3}\,A^{-2}]$

5. Two identical conductors 1 and 2 are placed on two frictionless conducting rails R and S in a uniform magnetic field directed vertically downward into the plane of the page. If conductor 1 is moved with a constant velocity in the direction as shown in figure, the force on conductor 2 will be along : 1



(A) $-\hat{i}$ (B) $-\hat{j}$

(C) $\hat{k}$ (D) $\hat{j}$

6. An ac voltage is given as v = 14 sin (314t) V. The average and the effective value of the voltage (in V) over a cycle are respectively : 1

(A) 14 and 7 (B) 10 and 14

(C) 0 and 10 (D) 10 and 0

7. The ratio of amplitude of electric field to the amplitude of the magnetic field associated with an electromagnetic wave propagating in glass (n = 1·5) is : 1

(A) 3×10^8 ms^{-1} (B) 2×10^8 ms^{-1}

(C) $3{\cdot}3 \times 10^{-9}$ ms^{-1} (D) 5×10^{-9} ms^{-1}

8. While studying photoelectric emission from a given surface, the wavelength of the incident radiation is changed from 600 nm to 400 nm, keeping the intensity of radiation the same. Then : 1

(A) cut-off potential will decrease. (B) cut-off potential will increase.

(C) saturation current will decrease. (D) saturation current will increase.

9. Radiation of wavelength 331 nm irradiates the following metals : 1

Metal	**Work Function (eV)**
Na	1·92
K	2·15
Ca	3·20
Mo	4·17

Which of the following statements is correct ?

(A) Only Na and K show photoelectric emission. (B) Only Mo will not show photoelectric emission.

(C) All of the given metals show photoelectric emission. (D) None of them show photoelectric emission.

10. The kinetic energy of a charged particle is increased to four times of its initial value. The de Broglie wavelength associated with the particle will : 1

(A) increase by 100% of its initial value.
(B) increase by 50% of its initial value.
(C) decrease by 25% of its initial value.
(D) decrease by 50% of its initial value.

11. Paschen series in spectrum of hydrogen atom lies in : 1

(A) infrared region
(B) ultraviolet region
(C) visible region
(D) partly in ultraviolet region and partly in visible region

12. In a reversed-biased p-n junction diode, the applied voltage mostly drops across : 1

(A) p-region only
(B) n-region only
(C) depletion region
(D) the diode

13. **Assertion (A) :** The work done, in taking a unit charge around a closed loop of an electric circuit involving cells and resistors in the loop, is zero. 1
Reason (R) : The potential at a point depends on the location of the point in the loop. After completing one round, the charge comes back to the point of start.

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).
(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).
(C) Assertion (A) is true, but Reason (R) is false.
(D) Both Assertion (A) and Reason (R) are false.

14. **Assertion (A) :** When a ferromagnetic substance is heated to high temperature it becomes paramagnetic in nature. 1
Reason (R) : The disappearance of magnetisation of a ferromagnet is abrupt and not gradual.

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).
(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).
(C) Assertion (A) is true, but Reason (R) is false.
(D) Both Assertion (A) and Reason (R) are false.

15. **Assertion (A) :** When a convex lens made of glass is immersed in water, its converging power increases. 1
Reason (R) : The focal length of a lens depends only on the radii of curvature of its two faces.

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).
(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).
(C) Assertion (A) is true, but Reason (R) is false.
(D) Both Assertion (A) and Reason (R) are false.

16. **Assertion (A) :** The conductivity of an n-type semiconductor is higher than that of a p-type semiconductor at a given temperature. 1

Reason (R) : The electrons being in the conduction band in n-type semiconductor are more mobile than the holes in the valence band in p-type semiconductor.

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Both Assertion (A) and Reason (R) are false.

SECTION B

Very short answer (VSA) questions of 2 marks each.

17. An electric dipole consists of two point charges +1 μC and −1 μC, held 10 cm apart. It is subjected to a uniform electric field of 100 N/C. Calculate the amount of work done in turning the dipole from its position of stable equilibrium to the position of unstable equilibrium, in the field. 2

18. (a) State Huygens principle. How did Huygens justify the absence of the backwave on a spherical wavefront ? 2

OR

(b) In a single-slit diffraction experiment, light of wavelength λ illuminates the slit of width 'a'. The diffraction pattern is observed on a screen kept at a distance D from the slits.
(i) Depict variation of intensity in the fringe pattern with the angular position of the fringes.
(ii) How is the linear width of central maximum affected when separation between the slit and the screen is decreased ?

19. A small bulb is placed at the bottom of a tank, containing a transparent liquid of refractive index $\sqrt{2}$, to a depth of 1 m. Calculate the area of the surface of the liquid through which light from the bulb emerges. 2

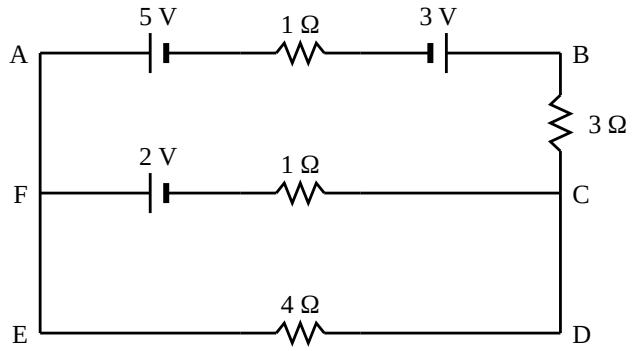
20. Draw the graph showing the variation of number of scattered alpha particles (N) detected with scattering angle (θ) in Geiger-Marsden experiment. Infer two conclusions from the graph. 2

21. The hole concentration in an intrinsic semiconductor is 5×10^8 m^{-3}. When it is doped with certain impurity, the electron concentration becomes 4×10^{12} m^{-3}. Find the new value of the hole concentration. Also identify the type of new semiconductor formed after doping. 2

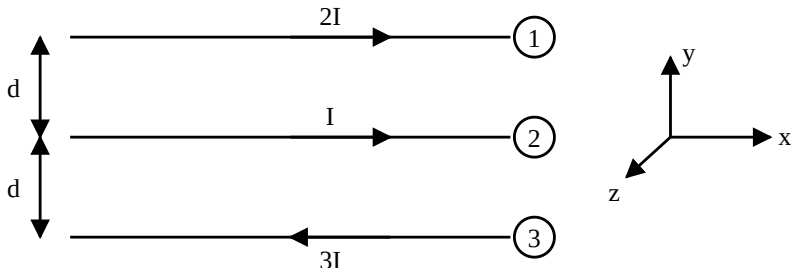
SECTION C

Short answer (SA) questions of 3 marks each.

22. State Kirchhoff's rules. Using these rules, find the current flowing through branch FC in the given circuit. 3



23. (a) The figure given below shows three straight long parallel conductors ①, ② and ③ kept in x-y plane, carrying currents 2I, I and 3I respectively as shown in figure. 3



Find the magnitude and direction of :

(i) net magnetic field at a point on conductor ① and

(ii) net magnetic force acting on unit length of conductor ①, due to conductors ② and ③.

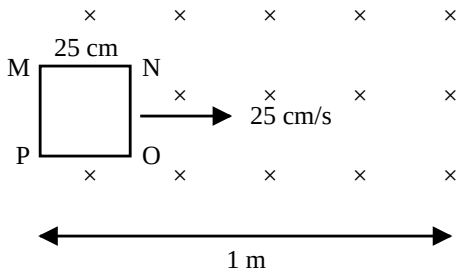
OR

(b) A rectangular loop of sides *l* and b and resistance 'R' is kept in a region in which the magnetic field varies as $B = B_0 \sin \omega t$.

(i) Derive expression for the emf induced in the loop.

(ii) Find the effective value of current that flows in the loop.

24. The figure given below shows a square-shaped loop MNOP of side 25 cm placed horizontally in a uniform magnetic field **B** directed vertically downward. The position of the loop at t = 0 s is as shown in figure. The loop is pulled with a constant velocity of 25 cm/s till it goes out of the field. 3



(a) What will be the direction of the induced current in the loop as it goes out of the field ? For how long would the current in the loop persist ?
(b) Plot graphs showing the variation of magnetic flux and magnitude of induced emf as a function of time.

25. What are infrared waves ? Why are these waves referred to as 'heat waves' ? Give any two uses of these waves. 3

26. (a) Explain how the dual aspect of matter is evident in the de Broglie relation. 3
(b) Radiation of wavelength λ is incident on a photosensitive surface. Find the de Broglie wavelength of electrons emitted from the surface. Assume that the work function of the surface is negligible.

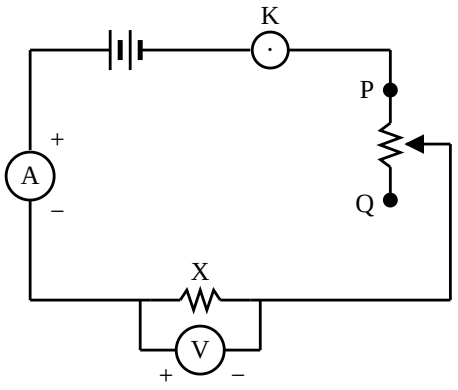
27. In the nuclear reaction : 3
$^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{A}_{2}X + {}^{1}_{0}n$
(a) Find the value of A.
(b) Calculate the amount of energy released in the reaction.
Given : $m(^{2}_{1}H) = 2{\cdot}014102$ u, $m(^{A}_{2}X) = 3{\cdot}016049$ u, $m(^{1}_{0}n) = 1{\cdot}008665$ u, 1 u = 931·5 MeV/c^2

28. With the help of a circuit diagram, explain the working of a full wave rectifier. Depict the input and output waveforms. 3

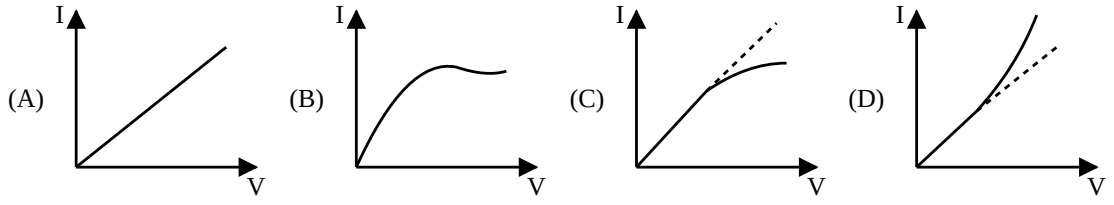
SECTION D

Case study based questions of 4 marks each.

29. A student sets up the circuit as shown in the figure to find the value of unknown resistance X and records a set of readings of the voltmeter and the ammeter by using the rheostat.



(i) If resistor X were made of manganin and readings for V and I are taken without switching off the circuit, the graph between V and I will be as :

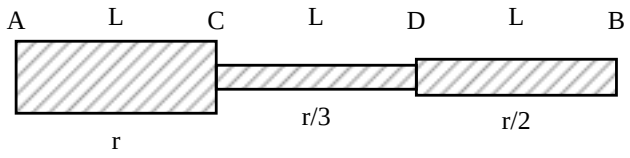


[1]

(ii) Error in the value of X obtained from different sets of voltmeter and ammeter readings, is :
(A) due to error in voltmeter reading only. (B) due to error in ammeter reading only. (C) equal to the sum of error in voltmeter reading and error in ammeter reading. (D) equal to error in voltmeter reading divided by the error in ammeter reading. [1]

(iii) If the movable end of rheostat is moved towards P, then :
(A) reading in ammeter decreases and reading in voltmeter increases. (B) readings in both voltmeter and ammeter increase. (C) reading in ammeter increases and reading in voltmeter decreases. (D) readings in both voltmeter and ammeter decrease. [1]

(iv) Suppose the unknown resistance X is replaced by a wire made of the same metal. This wire consists of three parts, of the same length L but has radii r, r/3 and r/2 as shown in the figure.



For a particular setting of the rheostat, let v_1, v_2 and v_3 be the value of drift velocities in parts AC, CD and DB. Then :
(A) $v_1 > v_2 > v_3$ (B) $v_2 > v_3 > v_1$ (C) $v_3 > v_2 > v_1$ (D) $v_1 = v_2 = v_3$ [1]

OR

(iv) Consider the same wire, as shown in figure in question (iv) (a) connected in place of X. For a particular setting of rheostat, let E_1, E_2 and E_3 be the value of electric fields in part AC, CD and DB.

Then :

(A) $E_1 = E_2 = E_3$ (B) $E_3 > E_2 > E_1$ (C) $E_2 > E_3 > E_1$ (D) $E_1 > E_2 > E_3$ [1]

30. An astronomical telescope consists of two converging lenses. One of them of large aperture and large focal length is called objective lens and the other one, of smaller focal length and smaller aperture is called the eyepiece. It is used to see distant objects which are not seen clearly with naked eyes. The image formed by the objective lens acts as an object for the eyepiece and the final image produced by the eyepiece is magnified.

(i) The images formed by the objective lens and the eyepiece are respectively :

(A) virtual, real (B) real, virtual (C) virtual, virtual (D) real, real [1]

(ii) The magnification produced by the telescope does ***not*** depend upon the :

(A) colour of light (B) focal length of objective lens (C) focal length of eyepiece (D) apertures of objective lens and eyepiece [1]

(iii) Which of the following statements is ***not*** correct for this telescope ?

(A) The focal length of objective lens (f_o) is larger than the focal length of eyepiece (f_e). (B) Its magnifying power can be increased by increasing the focal length of objective lens (f_o). (C) The distance between two lenses is more than ($f_o + f_e$). (D) The magnifying power can be decreased by increasing the focal length of eyepiece. [1]

(iv) An astronomical telescope has objective lens and eyepiece of focal lengths 80 cm and 4 cm respectively. To view the image in normal adjustment, the lenses must be separated by a distance of :

(A) 84 cm (B) 76 cm (C) 20 cm (D) 320 cm [1]

OR

(iv) Consider the telescope described in question (iv) (a). Its magnifying power in normal adjustment will be :

(A) 320 (B) 84 (C) 76 (D) 20 [1]

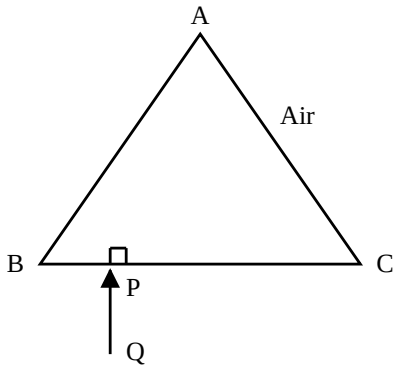
SECTION E

Long answer (LA) questions of 5 marks each.

31. (a) (i) Define refractive index of a medium in terms of speed of light. 5

(ii) Derive the relation for the refractive index (μ) of a prism in terms of angle of minimum derivation (δ_m) and angle of prism (A).

(iii) A ray of light QP is incident normally on the face BC of a triangular prism ABC of refractive index 1·5 kept in air, as shown in the figure. Trace the path of the ray as it passes through the prism and give relevant explanation.



OR

(b) (i) What is the difference between a ray and a wavefront ?

(ii) A plane wave is incident on a reflecting surface. Using Huygens principle, show how it is reflected from the surface. Hence, verify the law of reflection.

(iii) Depict refraction of a plane wave by a convex lens.

32. (a) (i) Define the terms (I) resonant frequency, and (II) power factor of a series LCR circuit. For what value of the power factor will the power dissipated in the circuit be maximum ? 5

(ii) An inductor of $\frac{5}{\pi}$ H, a capacitor of $\frac{50}{\pi}$ μF and a resistor of 400 Ω are connected in series across an ac voltage v = 140 sin (100π t) V. Calculate :

(I) impedance of the circuit, and

(II) rms value of current that flows in the circuit. (Take $\sqrt{2}$ = 1·4)

OR

(b) (i) Draw a labelled diagram of a step-up transformer. Obtain the ratio of secondary voltage to primary voltage in terms of number of turns in the two coils.

(ii) The number of turns in the primary and the secondary coil of an ideal transformer are 100 and 5000 respectively. If 3·3 kW power is supplied to the transformer at 220 V, find (I) current in the primary coil, and (II) output voltage.

33. (a) (i) Explain the following statements giving reason : 5

(I) An equipotential surface through a point is normal to the electric field at that point.

(II) When a dielectric is placed in an external electric field, the electric field inside the dielectric is less than that outside it.

(III) The potential difference between the plates of a charged parallel plate capacitor decreases when its plates are brought closer.

(ii) Obtain an expression for the work done to dissociate the system of three charges q, – 4q and 2q placed at the vertices A, B and C respectively of an equilateral triangle of side ‘a’.

OR

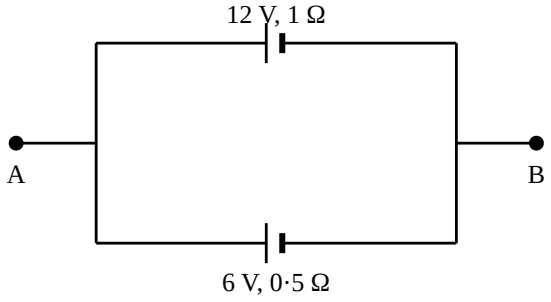
(b) (i) Answer the following giving reason :

(I) The electron drift speed is estimated to be only a few mm/s for currents in the range of a few amperes. How, then, is the current established almost the instant a circuit is closed ?

(II) A low voltage supply from which one needs high currents must have very low internal resistance. Why ?

(III) The assertion that V = IR is a statement of Ohm’s law is not true. Why ?

(ii) Two cells of emfs 12 V and 6 V are connected in parallel as shown in the figure. Their internal resistances are 1 Ω and 0·5 Ω respectively. Calculate the emf and internal resistance of the equivalent cell between points A and B.



END OF THE QUESTION PAPER

ANSWER KEY — SECTION A

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16
(A)	(C)	(B)	(B)	(A)	(C)	(B)	(B)	(B)	(D)	(A)	(C)	(A)	(C)	(D)	(A)

MARKING SCHEME AND WORKED SOLUTIONS

Marks for each step are shown in brackets, as in the CBSE marking scheme. Any correct alternative method earns full marks.

Q1. Answer (A). $R = (\rho_1 + \rho_2)l/A$ for the combined wire of length 2l and area A, so $\rho_{eq} = R \cdot A/(2l) = (\rho_1 + \rho_2)/2$.

Q2. Answer (C). $r = mv/(qB)$. Path 1 bends more, so $r_1 < r_2$: $m_1/q_1 < m_2/q_2$, that is $m_1/m_2 < q_1/q_2$.

Q3. Answer (B). Charge e passes any point of the orbit n times per second: $I = ne$.

Q4. Answer (B). $d\Phi/dt$ is an emf (volt = W/A = J s^{-1} A^{-1}): [M L^2 T^{-3} A^{-1}].

Q5. Answer (A). Conductor 1 moves along $-\hat{i}$, increasing the area enclosed between the rods and the inward flux. The induced current opposes this, and the force on conductor 2 makes it follow conductor 1: along $-\hat{i}$. (Directly: $B = -\hat{k}\,B$; in rod 1 the force on charges $q(-\hat{i}) \times (-\hat{k}) = -\hat{j}$ drives current down rod 1 and up rod 2; $F_2 = I(\hat{j}) \times (-\hat{k})B = -\hat{i}\,IB$.)

Q6. Answer (C). The average of a sine over a full cycle is 0. The effective (rms) value is $14/\sqrt{2} \approx 10$ V.

Q7. Answer (B). $E_0/B_0 = v = c/n = 3 \times 10^8/1.5 = 2 \times 10^8$ m s^{-1}.

Q8. Answer (B). A shorter wavelength means a higher frequency, so $eV_0 = h\nu - \varphi_0$ increases: the cut-off potential increases (the intended answer). Note: if 'the same intensity' means the same energy per unit area per second, the number of photons falls in the ratio 400 : 600, so the saturation current also decreases and (C) is true as well.

Q9. Answer (B). Photon energy $hc/\lambda = (6.63 \times 10^{-34} \times 3 \times 10^8)/(331 \times 10^{-9})$ J ≈ 3.75 eV. This exceeds the work functions of Na, K and Ca but not of Mo (4.17 eV).

Q10. Answer (D). $\lambda = h/\sqrt{(2mK)}$. Four times K halves λ: a decrease of 50%.

Q11. Answer (A). Paschen lines end on n = 3: wavelengths from about 820 nm to 1875 nm, all infrared.

Q12. Answer (C). The depletion region has almost no free carriers and a very high resistance, so nearly all the applied reverse voltage appears across it.

Q13. Answer (A). Work per unit charge = net change of potential. The potential has a definite value at each point, and the charge returns to its starting point, so the net change (and the work) is zero (Kirchhoff's loop rule). R explains A. Answer (A).

Q14. Answer (C). Above the Curie temperature a ferromagnet becomes paramagnetic: A is true. The domain structure breaks up with rising temperature and the magnetisation falls gradually (NCERT): R is false. Answer (C).

Q15. Answer (D). $1/f = (n_g/n_w - 1)(1/R_1 - 1/R_2)$: in water $(n_g/n_w - 1)$ is smaller, so the power decreases: A is false. f also depends on the refractive indices: R is false. Answer (D).

Q16. Answer (A). Electrons have a higher mobility than holes, so for the same doping an n-type material conducts better. R is the reason. Answer (A).

Q17. (2 marks) Answer: 2×10^{-5} J.
$p = qd = 10^{-6} \times 0.10 = 10^{-7}$ C m. Stable equilibrium $\theta = 0°$, unstable $\theta = 180°$. [½]
$W = pE(\cos 0° - \cos 180°) = 2pE = 2 \times 10^{-7} \times 100 = 2 \times 10^{-5}$ J. [1½]

Q18. (2 marks) Answer: (a) secondary wavelets, forward envelope; (b) width 2λD/a decreases.
(a) Every point of a wavefront is a source of secondary wavelets, which spread out with the speed of the wave; the forward envelope (common tangent) of these wavelets gives the new wavefront at a later time. [1]
Huygens assumed that the amplitude of the secondary wavelets is maximum in the forward direction and zero in the backward direction, so there is no backwave. [1]
OR (b) (i) Graph: intensity against θ with a broad, bright central maximum at θ = 0, zeros at θ = ±λ/a, ±2λ/a, …, and secondary maxima of rapidly falling intensity between them. [1]
(ii) Width of the central maximum = 2λD/a: decreasing D decreases it proportionally. [1]

Q19. (2 marks) Answer: π m² ≈ 3.14 m².
Light emerges only within the critical angle: sin C = 1/√2, C = 45°. [1]
Radius of the circle r = h tan C = 1 × 1 = 1 m; area = πr² = π m² ≈ 3.14 m². [1]

Q20. (2 marks) Answer: N falls steeply with θ; atom mostly empty; tiny massive nucleus.
Graph: N very large at small θ and falling steeply (as $1/\sin^4(\theta/2)$) with increasing θ; only very few particles at θ near 180°. [1]
Conclusions: most of the atom is empty space, since most α-particles pass almost undeviated; the positive charge and almost all the mass are concentrated in a tiny nucleus, since a very few are scattered through large angles (some even bounce back). [½ + ½]

Q21. (2 marks) Answer: 6.25×10^4 m^{-3}; n-type.
$n_i = 5 \times 10^8$ m^{-3}. $n_e n_h = n_i^2$: $n_h = (5 \times 10^8)^2/(4 \times 10^{12}) = 25 \times 10^{16}/(4 \times 10^{12}) = 6.25 \times 10^4$ m^{-3}. [1]
$n_e \gg n_h$: it is an n-type semiconductor. [1]

Q22. (3 marks) Answer: 1/3 A, from C to F.
Junction rule: the sum of the currents entering a junction equals the sum leaving it (charge conservation). Loop rule: the algebraic sum of the changes of potential round any closed loop is zero (energy conservation). [1]
A, F, E are one node (0 V); C, D are one node (potential x). With the cells as drawn (positive plates of the 5 V and 2 V cells towards the left, of the 3 V cell towards B), the currents from the left node to C are: top branch (−2 − x)/4, middle branch (−2 − x)/1, bottom branch −x/4. Their sum is zero: −10 − 6x = 0, x = −5/3 V. [1]
Current in FC = −2 + 5/3 = −1/3 A: 1/3 A, flowing from C to F. [1]

Q23. (3 marks) Answer: (a) $\mu_0 I/(4\pi d)$ along −z; $\mu_0 I^2/(2\pi d)$ per unit length along +y; (b) $\varepsilon = -B_0 lb\omega \cos \omega t$; $I_{rms} = B_0 lb\omega/(\sqrt{2}R)$.
(a) (i) At ①: from ② (current I along +x, distance d) $B_2 = \mu_0 I/(2\pi d)$ along +z; from ③ (current 3I along −x, distance 2d) $B_3 = \mu_0(3I)/(2\pi \cdot 2d) = 3\mu_0 I/(4\pi d)$ along −z. [1]
Net $B = 3\mu_0 I/(4\pi d) - 2\mu_0 I/(4\pi d) = \mu_0 I/(4\pi d)$, along −z. [1]
(ii) $F/l = I_1 \times B = 2I \times \mu_0 I/(4\pi d) = \mu_0 I^2/(2\pi d)$; direction (+x) × (−z) = +y, away from ② and ③ (② attracts with $\mu_0 I^2/(\pi d)$, ③ repels with $3\mu_0 I^2/(2\pi d)$). [1]
OR (b) (i) With B normal to the loop: $\Phi = B \cdot lb = B_0 lb \sin \omega t$. $\varepsilon = -d\Phi/dt = -B_0 lb\omega \cos \omega t$; peak $\varepsilon_0 = B_0 lb\omega$. [2]
(ii) $I_0 = B_0 lb\omega/R$, so $I_{rms} = B_0 lb\omega/(\sqrt{2}\,R)$. [1]

Q24. (3 marks) Answer: clockwise (seen from above), for 1 s (t = 3 s to 4 s).
(a) The field region is 1 m wide and the loop starts at its left edge. For the first (100 − 25)/25 = 3 s the loop is wholly inside: the flux is constant and there is no current. As it leaves, the downward flux decreases, so the induced current makes a downward field: clockwise as seen from above (M → N → O → P). [1]
The current lasts while the loop is leaving: 25 cm/(25 cm/s) = 1 s (from t = 3 s to t = 4 s). [1]
(b) Flux: constant at B × 0.0625 Wb from 0 to 3 s, then falling linearly to zero at 4 s. Emf: zero from 0 to 3 s, constant B l v = B × 0.25 × 0.25 = 0.0625B V from 3 s to 4 s, zero after. [1]

Q25. (3 marks) Answer: 700 nm – 1 mm; readily absorbed and heat matter.
Infrared waves are electromagnetic waves of wavelength about 700 nm to 1 mm, between visible light and microwaves, given out by hot bodies and molecules. [1]
They are called heat waves because water molecules and most other molecules readily absorb them; this increases their thermal motion and heats the substance. [1]
Uses: physiotherapy (warming), remote controls of TV and other devices, night-vision and thermal imaging, greenhouses, weather forecasting. [½ + ½]

Q26. (3 marks) Answer: $\lambda_e = \sqrt{(h\lambda/2mc)}$.
(a) $\lambda = h/p$: the left side, λ, is a wave property and the right side, the momentum p, is a particle property; h links the two, so the relation states that matter has both. [1]
(b) With $\varphi_0 \approx 0$, the electron's kinetic energy $K = hc/\lambda$. [1]
$\lambda_e = h/\sqrt{(2mK)} = h/\sqrt{(2mhc/\lambda)} = \sqrt{(h\lambda/(2mc))}$. [1]

Q27. (3 marks) Answer: A = 3; ≈ 3.25 MeV.
(a) Mass numbers balance: 2 + 2 = A + 1, so A = 3 (the product is $^{3}_{2}He$). [1]
(b) $\Delta m = 2 \times 2.014102 - (3.016049 + 1.008665) = 4.028204 - 4.024714 = 0.003490$ u. [1]
$Q = 0.003490 \times 931.5 \approx 3.25$ MeV. [1]

Q28. (3 marks) Answer: both half-cycles rectified.
Circuit: a centre-tapped transformer secondary with diode D_1 from one end and D_2 from the other, both joined to the load R_L, whose other end goes to the centre tap. [1]
In one half-cycle end A is positive: D_1 conducts and D_2 is reverse biased; in the next half-cycle end B is positive: D_2 conducts. In both half-cycles the current flows through R_L in the same direction, so the output is a unidirectional (pulsating dc) voltage. [1]
Waveforms: input a sine wave; output a series of positive half-sine pulses, one in every half-cycle (frequency twice the input). [1]

Q29. (4 marks) Answer: (i) A; (ii) C; (iii) B; (iv) B (OR: C).
(i) (A) Manganin has a very small temperature coefficient of resistance, so its resistance stays nearly constant even as it warms: V–I is a straight line through the origin. [1]
(ii) (C) X = V/I, so the (fractional) errors of the two readings add. [1]
(iii) (B) End Q is not connected, so the rheostat's working part is between P and the slider. Moving the slider towards P reduces that resistance: the current rises, and so does the voltage across X. [1]
(iv) (B) The parts are in series and carry the same current; $v_d = I/(neA) \propto 1/r^2$: CD (r/3) has the largest, then DB (r/2), then AC (r): $v_2 > v_3 > v_1$. [1]
OR (iv) (C) $E = \rho J = \rho I/A \propto 1/r^2$: $E_2 > E_3 > E_1$. [1]

Q30. (4 marks) Answer: (i) B; (ii) D; (iii) C; (iv) A (OR: D).
(i) (B) The objective forms a real, inverted image of the distant object; the eyepiece, acting as a magnifier, forms a virtual final image. [1]
(ii) (D) $m = f_0/f_e$ depends on the focal lengths (which depend slightly on colour), not on the apertures; the aperture affects brightness and resolution. [1]
(iii) (C) In normal adjustment the separation is $f_0 + f_e$, and for the final image at the near point it is less; it is never more. [1]
(iv) (A) $f_0 + f_e = 80 + 4 = 84$ cm. [1]
OR (iv) (D) $m = f_0/f_e = 80/4 = 20$. [1]

Q31. (5 marks) Answer: (a) $\mu = \sin[(A + \delta_m)/2]/\sin(A/2)$; total internal reflection at AB, emerges normally through AC; (b) $i = r$.

(a) (i) Refractive index $n = c/v$, the ratio of the speed of light in vacuum to its speed in the medium. [1]

(ii) For a ray through the prism: $r_1 + r_2 = A$ and $\delta = i + e - A$. At minimum deviation $i = e$ and $r_1 = r_2 = r$, so $r = A/2$ and $i = (A + \delta_m)/2$. [1]

$\mu = \sin i/\sin r = \sin[(A + \delta_m)/2]/\sin(A/2)$. [1]

(iii) Taking ABC as equilateral (as drawn): the ray enters BC normally, undeviated, and meets face AB at an angle of incidence of 60°. The critical angle is $\sin^{-1}(1/1.5) \approx 41.8°$; $60° > 41.8°$, so it is totally reflected at AB. [1]

The reflected ray travels towards AC and meets it normally (at 0° incidence), so it leaves through AC without deviation. [1]

OR (b) (i) A ray is the direction in which light energy travels; a wavefront is the surface of points vibrating in the same phase. Rays are perpendicular to wavefronts. [1]

(ii) Diagram: plane wavefront AB meets the mirror at A at an angle i. While the disturbance from B travels BC = vt to the mirror, a secondary wavelet of radius AE = vt spreads from A. The tangent CE from C to this wavelet is the reflected wavefront. [1½]

Triangles EAC and BAC are congruent (common AC, right angles at E and B, AE = BC), so $\angle i = \angle r$: the law of reflection. [1]

(iii) Diagram: a plane wavefront meets the convex lens; the central part travels through the thickest glass and is delayed most, so the emerging wavefront is spherical, converging to the focus F. [1½]

Q32. (5 marks) Answer: (a) $\cos\varphi = 1$; $Z = 500\ \Omega$, $I_{rms} = 0.2$ A; (b) 15 A, 11 000 V.

(a) (i) (I) Resonant frequency: the frequency at which $X_L = X_C$ and the current is maximum: $\omega_0 = 1/\sqrt{(LC)}$ ($f_0 = 1/(2\pi\sqrt{(LC)})$). [1] (II) Power factor: $\cos\varphi = R/Z$, the ratio of the average power to $V_{rms}\, I_{rms}$. The power is maximum when $\cos\varphi = 1$ (at resonance). [1]

(ii) $\omega = 100\pi$: $X_L = 100\pi \times 5/\pi = 500\ \Omega$; $X_C = 1/(100\pi \times 50 \times 10^{-6}/\pi) = 200\ \Omega$. (I) $Z = \sqrt{(400^2 + 300^2)} = 500\ \Omega$. [1½]

(II) $V_{rms} = 140/\sqrt{2} = 140/1.4 = 100$ V; $I_{rms} = 100/500 = 0.2$ A. [1½]

OR (b) (i) Diagram: primary and secondary coils (secondary with more turns) on a laminated soft-iron core. The same flux links every turn: $\varepsilon_s = -N_s\, d\Phi/dt$ and $\varepsilon_p = -N_p\, d\Phi/dt$. [2]

For an ideal transformer $V_s/V_p = N_s/N_p$. [1]

(ii) (I) $I_p = P/V_p = 3300/220 = 15$ A. [1] (II) $V_s = 220 \times 5000/100 = 11\,000$ V. [1]

Q33. (5 marks) Answer: (a) work $= 10q^2/(4\pi\varepsilon_0 a)$; (b) 8 V, 1/3 Ω.

(a) (i) (I) No work is done in moving a charge along an equipotential surface ($dW = qE\cdot dl = 0$), so $E\cdot dl = 0$ for every displacement on it: E is normal to the surface. [1]

(II) The field polarises the dielectric; the induced surface charges set up a field opposite to the applied one, so the net field inside is reduced ($E = E_0/K$). [1]

(III) With the charge Q fixed, $C = \varepsilon_0 A/d$ increases as d decreases, so $V = Q/C$ decreases ($V = Ed$ with $E = \sigma/\varepsilon_0$ unchanged). [1]

(ii) $U = k[q(-4q) + (-4q)(2q) + (2q)(q)]/a = k(-4 - 8 + 2)q^2/a = -10q^2/(4\pi\varepsilon_0 a)$. [1]

Work needed to dissociate the system (take the charges to infinity) $= -U = 10q^2/(4\pi\varepsilon_0 a)$. [1]

OR (b) (i) (I) When the circuit is closed, the electric field is set up throughout the conductor almost at once (at nearly the speed of light), so the free electrons everywhere start drifting at the same time. [1] (II) $I = E/(R + r)$; for a large current the internal resistance must be small, otherwise the current is limited and much energy is wasted as heat in the source (and the terminal voltage drops). [1] (III) $V = IR$ defines resistance and holds for every conductor; Ohm's law is the statement that R is constant, $V \propto I$, independent of V and I, which is true only for ohmic conductors. [1]

(ii) Both positive terminals face A, so the cells aid each other in parallel: $\varepsilon_{eq} = (\varepsilon_1 r_2 + \varepsilon_2 r_1)/(r_1 + r_2) = (12 \times 0.5 + 6 \times 1)/1.5 = 8$ V. [1]

$r_{eq} = r_1 r_2/(r_1 + r_2) = 0.5/1.5 = 1/3\ \Omega$. [1]

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